Small Business Innovation Research/Small Business Tech Transfer

Regeneratively Cooled Ceramic Matrix Composite Nozzle Assembly for Reduced Weight, Phase I

Completed Technology Project (2018 - 2019)

Project Introduction

All rocket missions benefit from having lower structural mass and higher specific impulse, both of which contribute to larger payload fractions and therefore lower mission cost. High temperature materials such as ceramic matrix composites (CMCs) are an avenue to lower engine mass because of the low density and high specific strength of the material. They also have a high maximum temperature and so contribute to high specific impulse by reducing the thermal load that must be removed from the nozzle structure, keeping the heat in the exhaust stream where it belongs. However, even the maximum temperature of CMCs is not high enough for stoichiometric methane-oxygen or hydrogen-oxygen flame conditions.

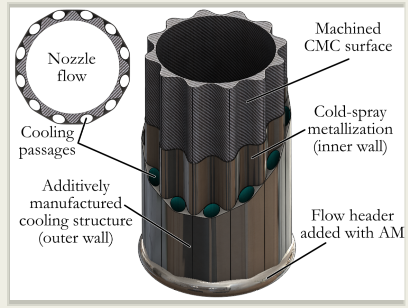
In this Phase I effort, PSI will develop a regenerative cooling architecture and manufacturing method for a combined CMC/metal structure. The major difficulties encountered so far in adding fuel cooling to CMC nozzles is that CMCs are typically permeable and have low thermal conductivity. PSI will address these challenges using cold-spray metallization and metal additive manufacturing to build metal cooling passages on a corrugated CMC nozzle.

If the proposed project is successful, it will result in a CMC/metal structure capable of withstanding combustion chamber, throat, and nozzle conditions by using regenerative cooling. The Phase I program will end with validated thermal design and manufacturing methods for a full regenerative CMC nozzle. This technology is applicable to a range of nozzle sizes from the 1.2 klbf MSFC "workhorse" nozzle configuration which would be targeted in a Phase II project, through booster-scale nozzles. At the end of the Phase I project, a manufacturing prototype of the CMC/metal cooling structure and design and test data will be provided to NASA.

Anticipated Benefits

The proposed regeneratively cooled ceramic matrix composite combustion chamber and nozzle technology would be immediately applicable to upper-stage rocket engines and small in-space and powered descent engines. With additional development, the same technology could be applied to large nozzles, which would yield an even greater system benefit than small nozzles due to their greater fraction of the total system mass for a large rocket.

Cooled ceramic matrix composites are applicable to combustors and hot structure for flight vehicles. For hypersonic airplanes, the technology is applicable to leading edges, combustor liners, and jet impingement surfaces. It can be used with fuel as coolant as in the rocket engine case, or with separate cooling loops including cryogenic, phase-change, or refrigerated. The temperature capabilities of existing CMC parts can be increased, or lower-cost CMCs could be substituted, enabled by cooling.



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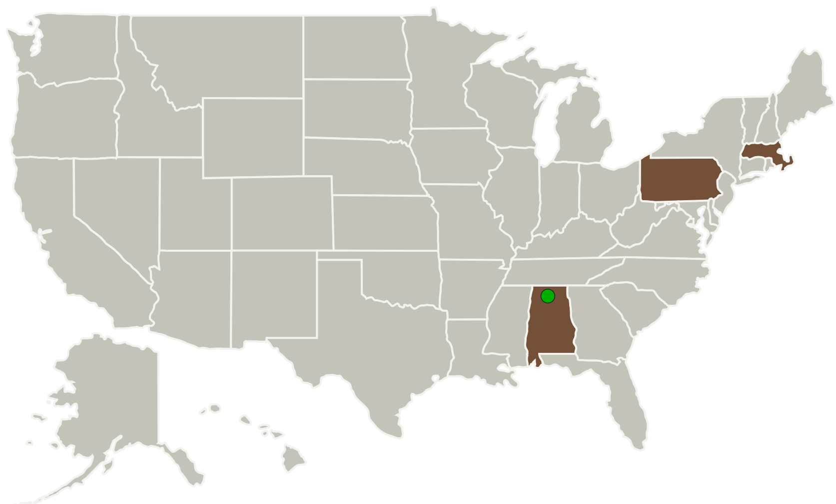
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Physical Sciences, Inc.	Lead Organization	Industry	Andover, Massachusetts
Concurrent Technologies Corporation, Inc.	Supporting Organization	Industry	Fayetteville, North Carolina
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations	
Alabama	Massachusetts
Pennsylvania	

Project Transitions

July 2018: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Physical Sciences, Inc.

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

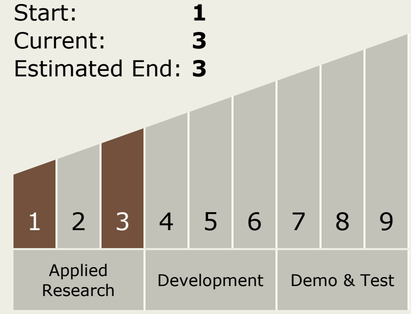
Carlos Torrez

Principal Investigator:

Sean Torrez

Technology Maturity (TRL)

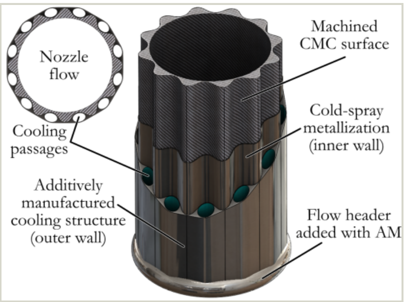
Start: **1**
Current: **3**
Estimated End: **3**



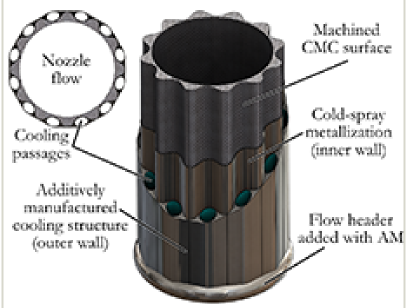
August 2019: Closed out

Closeout Documentation:
- Final Summary Chart*(https://techport.nasa.gov/file/137895)*

Images



Briefing Chart Image
Regeneratively Cooled Ceramic Matrix Composite Nozzle Assembly for Reduced Weight, Phase I
(https://techport.nasa.gov/image/136535)



Final Summary Chart Image
Regeneratively Cooled Ceramic Matrix Composite Nozzle Assembly for Reduced Weight, Phase I
(https://techport.nasa.gov/image/135904)

Technology Areas

Primary:

- TX01 Propulsion Systems
  └ TX01.1 Chemical Space Propulsion
    └ TX01.1.3 Cryogenic

Target Destinations

Earth, The Moon, Mars